A SHORT HISTORY OF FLOUR MILLING

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POUNDING AND RUBBING

Among all the industries of the world, flour milling may justly claim to have had the longest continuous existence. Its origin goes back uncounted centuries beyond the reach of written or pictured records, for grain was unquestionably used for human food in prehistoric times, and wherever grain was so used, there likewise was the germ of flour milling. Although the cultivation of wheat has not been traced to the Paleolithic age, stores of wheat ears or grain belonging to Neolithic man have been discovered in many parts of central and eastern Europe. Even in those days wheat culture seems to have been of considerable antiquity, for the discoveries include specimens of several kinds of wheat.

Thus it is that when wheat growing and flour grinding emerge from obscurity into the comparative clearness of historic antiquity, they appear as already ancient institutions, vested in many cases with a profound religious significance. Wheat was a direct gift of the gods among the Egyptians and Greeks, and for the Chinese wheat was a grant from heaven, celebrated until recent times by an annual sowing by the

emperor, a custom introduced by the semi-mythical Shennung.

Of the process of converting wheat and other grains into edible food in prehistoric times we know, of course, little beyond what can be deduced from later evidence and from scanty relics. In general, prehistoric man pounded his grain, and did not rub or roll it; the saddle stone, the earliest form of the real grinding mill, belongs to the dawn of recorded history. The transition from the pounding process to one of grinding by friction represents the first of the great steps in the development of flour milling, and this step had begun to be taken by the time that the first enduring records of the milling industry were made. This transition may, indeed, fairly be said to mark the dawn of civilization, as we understand the term, and in the savage tribes under observation in recent years it remains true that the degree of civilization goes hand in hand with the refinement of the milling process.

EARLIEST STAGES

It is unnecessary for a review of flour milling history to take much account of the primitive grain pounding stage, partly because of the scarcity of material, and still more because there was nothing which could be called a real development in the art of milling so long as the pounding process predominated. The one essential fact is that the preparation of grain for human food by crushing or pounding it unquestionably existed for thousands of years before the beginnings of recorded history, and that during these uncounted centuries the only significant changes in the process concerned the shape of the instruments used. The bedstone tended to become more cup-shaped, the pounding stone more pointed, and as these forms were accentuated, it is quite possible that individual grain pounders often used their pestles with a twisting

motion, thus rubbing and bruising the grain as well as crushing it.

Presumably it was from observation of the fact that such a twisting motion of the crushing stone was more effective than a mere downright blow that flour milling made its first real advance. Certainly, in so far as direct evidence is supplied by unquestioned pounding and bed stones which have been unearthed, there was no tendency in prehistoric times for the concave surface to become really deep, so as to approximate the much later mortar, and with the elongated pounding stones generally in use, it must have become apparent that a much greater rubbing surface could be secured by using the side of the stone than by employing simply the point. The first real grinding, as distinct from mere pounding, was undoubtedly a combination process, the grain being first broken with blows of the pounding stone, and then rubbed into a coarse meal. Little by little the rubbing part of the process increased in relative importance, until the entire work of reducing the grain to meal was accomplished by this method.

THE SADDLE STONE

At this point flour milling may be said to have begun, and with it come the earliest enduring records, showing not only the instruments, but how they were used. Dates are at best mere approximations, but there is good reason to believe that the saddle stone goes back some four thousand years before the beginning of the Christian era. Chaldea, the real cradle of civilization and of the arts, was particularly famous for its grain, and while there exist only a few traces of the saddle stone as used among the Chaldeans, there are enough of these to make it altogether likely that wheat and other grains were converted into human food by a rubbing and not a pounding process.

The best evidence of the existence of the saddle stone

among the Chaldeans is the fact that in the civilizations which borrowed most of their early glory from Chaldea the saddle stone appears as the established device for grinding grain. This is above all true of Egypt. A number of statuettes have been discovered, at least one of them attributed to the period of the Third Dynasty, or about 2300 B. C., which show kneeling figures grinding grain. In practically every case, the lower stone has a flat or slightly concave upper surface, generally inclined slightly away from the grinder, while the upper stone is in the form of a roller, somewhat longer than the extreme width of the lower stone.

Whether this upper stone was rolled or pushed back and forth over the surface of the saddle stone is an open question, but probably both motions were used. Some of the Egyptian statuettes show an upper stone with one surface flattened, indicating that the grain was rubbed beneath it with little or no rotary motion; in other instances the upper stone is nearly if not quite round. In either case, however, there can have been practically no pounding of the grain; the meal was produced by a gradual crushing and rubbing, with friction playing a larger part than the direct pressure which would result from using the upper stone simply as a roller.

EGYPT AND PALESTINE

From Egypt we secure our earliest pictorial records of flour milling, and these, including the statuettes and the many decorations on monuments and tombs, are sufficiently varied and numerous to give a clear idea of the processes employed. The most important literary records of milling three thousand years ago, however, come to us, not from the Egyptians, but from the Hebrews. The Old Testament is full of references to the grinding of wheat, to bread and to bakers, and from these references we can obtain a considerable insight not only into

milling and baking methods, but also into the economic and social status of the allied industries. For this reason, it is worth while to consider briefly the evidence which the Old Testament presents on the subject.

In ancient Palestine the bakers seem to have been much more important than the millers, for we find no reference to millers as a distinct class, and the flour mills, where they were not simply household appliances, seem to have been almost universally operated by slaves—a custom which persisted far into the days of the Roman Empire. Throughout the period of the Jewish residence in Egypt and the subsequent migrations it is probable that the ordinary domestic mill—in other words, a crude mortar or a saddle stone—on which each household ground its own grain was the only known type. Among the Egyptians, however, and some of the other nations with which the Jews early came into contact, there were certainly mills established in the royal or other large households, worked by slaves, and supplying flour for the royal family and retinue. There may also have been semi-public mills dating from very early times. For example, when the Philistines captured Samson and put out his eyes, they "brought him down to Gaza, and bound him with fetters of brass, and he did grind in the prison house."

That all flour milling outside of the individual household was carried on almost exclusively by slaves is unquestionable; the interesting problem is to determine how far it was managed by the authorities as a public service. Not to any great extent, probably, or there would be more specific references to it, as there are to baking, but it seems likely that most of the local prisons among the Hebrews maintained mills in which grain was ground for the people at large.

However, most of the early grinding was certainly done at home, and each man's millstones were regarded as among his most important possessions. Thus it was specifically forbidden

for any one to accept millstones as collateral for a loan: "No man shall take the nether or the upper millstone to pledge; for he taketh a man's life to pledge." As laws are made only when there are evils to correct, it is clear that some of the Jews were in the habit of mortgaging their domestic flour mills, and then, on the foreclosure of the mortgage, no longer able to keep themselves alive, becoming public charges.

That these household millstones were saddle stones and not mere pounders or crushers is clearly indicated by the familiar reference in Exodus to the slave woman "behind" the mill. The saddle stone is the only known form of early grain grinding device which has any discernible "behind" and "before," and thus the reference provides a quite sufficient description of the milling equipment, supported by all the evidence obtainable from Egypt itself at the period mentioned by the story.

THE EARLY BAKERS

If the millers of flour are neglected in the Old Testament records, the bakers are in a very different position, and through the frequent references to them, and the still more numerous references to bread, we can obtain some notion of the importance of the bread-making industries among the early Hebrews. The earliest reference to a professional baker is, of course, to be found in the well-known story in Genesis. In this case the baker was not a Jew, but an Egyptian, but the Jews certainly saw nothing unusual in Pharaoh's having such an official, and he seems to have been a personage of some importance in the royal palace.

Many years later we find a situation suggesting, at least, a commercial bakery on a more modern basis, and also the existence of something resembling a bakers' association. The Chaldeans had been making a vast amount of trouble for the

Jews, and King Zedekiah, at his wits' ends to know what to do, directed the prophet Jeremiah to pray for the people. Thereupon Jeremiah, always ready to foretell disaster, announced that the Chaldeans, who had temporarily withdrawn, would shortly return, "and fight against this city, and take it, and burn it with fire." This was exactly what Zedekiah had not bargained for, so the unwelcome prophet was straightway thrown into prison. After he had remained there for a few days, however, the king listened to his plea for liberty, and "commanded that they should commit Jeremiah into the court of the prison, and that they should give him daily a piece of bread out of the bakers' street, until all the bread in the city were spent."

It would be immensely interesting to know just what the "bakers' street" really was. Apparently by this time the Jews, at least in Jerusalem, had turned away from home baking sufficiently so that the bakers formed a definite group, localized by having their establishments in a single street. This is a very different situation from the one revealed in all the earlier references to bakers, for the "bakers' street" cannot have had anything to do with the royal palace. Did the bakers go there voluntarily, or was a certain region officially designated for them? Did they have an organization of their own, so as to distribute such royal requisitions as this one of Zedekiah's among the individual bakers? The answer to each of these questions is probably affirmative, to some extent at least, for it is inconceivable to think of a group of tradesmen living close together and all working at the same industry without establishing some measure of industrial organization.

This, in turn, raises a question as to how and where the bakers secured their flour. With home baking evidently superseded to some extent by the commercial process, it would be natural to assume that home milling followed a similar course. To some extent, perhaps, it did so. The bakers probably did much of their own grinding, or, as is still more likely, they

secured flour from the semi-public prison mills. In general, however, the situation among the Hebrews seems to have been the exact reverse of conditions as they were subsequently for the better part of two thousand years. In other words, home milling and commercial baking were the rule, as opposed to the commercial or public milling and home baking of later days.

In summary, the evidence afforded by the Old Testament, taken in conjunction with that provided by Egypt, indicates that flour milling from about 2000 B. C. to the beginning of the Macedonian period seventeen hundred years later showed little or no industrial or mechanical development, although the allied industry of baking seems to have undergone something resembling a real commercial organization. Grain was ground either at home, in the royal palaces and great households, or in the prisons, and practically always by slave or menial labor whenever such labor was procurable. The farmer, of course, ground his own grain, just as he does in Palestine today; the city dweller either bought grain and ground it himself or went to the "bakers' street" and bought his bread ready baked. The nearest approach to trade in flour must have been among the bakers themselves, but the complete lack of any references to the buying or selling of flour—and this among a people conspicuous from the very beginning for their commercial activity—is virtual proof that the flour business as a distinct occupation among the Jews amounted to very little.

IN HOMERIC TIMES

About the time that Solomon was building up Jerusalem into a great city, the historical tradition of the ancient Greeks was beginning with the story of the fall of Troy. Presumably some five or six hundred years intervened between the actual destruction of Troy by the Greeks—assuming that it ever was so destroyed at all—and the final composition of the two

mighty epics which have made the event enduringly famous; the pictures of Greek life presented by the Iliad and the Odyssey belong essentially to the seventh or eighth century before Christ, and not to the era in which the events are supposed to have taken place. None the less, these pictures are of remarkable value, above all by reason of their clearness, and there is in the twentieth book of the Odyssey a reference to flour milling which, when checked against the many other references to flour and bread in the Homeric poems, gives us a striking picture of the milling industry some twenty-six hundred years ago.

The passage occurs at the point where Odysseus, after many wanderings, has returned from the siege of Troy to his home, where he is at first unrecognized. His house is virtually in possession of his wife's numerous suitors, whom Odysseus plans to slay, with the help of his son, Telemachus. The appointed day arrives, and Odysseus, still vexed by doubts as to the outcome, calls on the chief of the gods for a sign of impending victory. "Let some one," he prays, "of the folk that are waking show me a word of good omen within."

The answer straightway follows: "A woman, a grinder at the mill, uttered a voice of omen from within the house hard by, where stood the mills of the shepherd of the people. At these handmills twelve women in all were wont to bestir themselves, making flour of barley and of wheat, the marrow of men. Now all the others were asleep, for they had ground out their task of grain, but this one alone did not yet rest, being the weakest of all. She now stayed her mill, and spake a word, a sign to her lord."

Such was the flour milling establishment in the home of a Greek prince in the period when the Homeric poems were composed. It was even called a "mill," the Greek word mylé (pronounced very much like the German mühle) being cognate with the Latin mola, whence came, likewise in Latin, the

diminutive molina, a "little mill," this, in turn, passing into early English as myln, whence the transition to "mill" is easy. Whether Odysseus had twelve mills, each with a single operative, or a smaller number, with the women working in shifts, is not entirely clear from the passage. Probably, however, there was an individual mill for each of the twelve women, as otherwise they would presumably not have all been allowed to sleep at the same time,—except, that is, the one "weakest of all" who had not finished her allotment.

Presumably the same women, with the same machinery, ground both wheat and barley, although the one in question refers specifically only to her toil in making barley flour. The two cereals are mentioned together in the description preceding her speech. It would be interesting to know whether they were used separately, or combined in some form of mixed flour. The standard Homeric word for bread, sitos, has been interpreted by most lexicographers to mean wheat bread primarily, and perhaps exclusively. On the other hand, the word meaning wheat flour, aleiar, appears far less often than alphiton, which certainly indicates a flour made wholly or in part of barley. All varieties of flour were constantly characterized as "white," so the alphiton was probably not a straight barley flour, but a blend with wheat.

Unlike the Jews or the Egyptians, the Greeks were essentially a seafaring people, and flour formed a regular part of the food supply for the crews of the Greek ships. Thus, in the second book of the Odyssey, when Telemachus goes off to seek his father, he gives the following order for the victualing of his ship: "Fill twelve jars with sweet wine, and close each with its lid, and pour me barley meal into well-sewn skins, and let there be twenty measures of the grain of bruised barley meal." The custom of packing flour for shipment in leather sacks was practically universal throughout the Greek world.

GREEK FLOUR QUALITY

Regarding the quality of this flour, it is significant that the adjective almost invariably applied to flour or bread in the Homeric poems is leukos, which means "bright," "white." The whiteness of all flour of the Homeric period seems to have been its most salient characteristic, and certainly, if the bread had been coarse or dark, some other word than "white" would have been found to supply its chief description. It was just this kind of bread which appears repeatedly in the Homeric poems as "the marrow of men," the phrase being a close equivalent to "the staff of life." The insistence on whiteness suggests that there must have been some degree of separation of the bran from the kernel of the grain in the Greek milling process, and this idea is supported by the fact that Odysseus, like many a country miller of later times, kept pigs, and fed them on "husks," which almost certainly means the offals of wheat and barley milling.

This question of separation in flour milling involves various mechanical considerations as to the type of mill used by the early Greeks. It has been generally assumed that the Homeric flour mill was essentially like the Scottish quern, and the Butcher and Lang translation of the Odyssey actually uses the word "quern" as a rendering for mylé. Professor Yates describes the ancient Greek mill as "two round flat stones about two feet in diameter. The upper stone is turned by a handle inserted at one side, and has a hole in the middle into which the corn [wheat] is poured. By the process of grinding the corn makes its way from the center, and is poured out in the state of flour at the rim." "There is no doubt," he adds, "that this is the flour mill in its most ancient form."

Richard Bennett, on the other hand, maintains that the Homeric mill was simply a flat or hollowed stone, on which the grain was pounded and crushed by another stone held in the

hand. It is hard to see how anything approaching "white" flour could have been evolved from such a crude process.

The archeological evidence in favor of the crushing stone as against the rotary mill is, however, very strong. Schliemann, in describing the relics found in the ruins of Troy, points out that "rudely cut, nearly globular, stone instruments for flour grinding are very numerous in all the four lower prehistoric cities; I could have collected thousands of them."

Another, and a more likely, possibility for the mill equipment of Odysseus is the saddle stone. Schliemann found great numbers of saddle stone mills in the ruins of Troy, although his description is unsatisfactorily vague; Schliemann was more of an archeologist than a milling expert. He maintained that such stones as he found were unsuitable for flour making; "only a kind of groats," he says, "could have been made in this way, not flour; and the bruised grain could not have been used for making bread; in Homer we find it used for porridge, and also for strewing on roasted meats." Bennett, on the other hand, maintains that excellent flour could be ground with the saddle stone. As the high quality of the Ithacan flour is so well attested, it follows either that Bennett is right and Schliemann wrong, or that Odysseus actually had more efficient milling machinery at his disposal than the saddle stone, the crusher or the mortar.

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THE REVOLVING MILL

The problem of the type of flour mill used by the ancient Greeks leads directly to the second great step in the development of flour milling, the first having been the substitution of attrition for pounding in the primitive grinding of grain. The cause which brought about the change from the saddle stone to the revolving quern was the desire, not to produce a better quality of flour, but to economize power. Obviously, as long as the milling process was based on a backward and forward motion of the grinding or crushing stone, the size of the mill was automatically limited by the fact that no mill could be larger than one person (generally one slave woman) could operate by hand. In the early days slave or prison labor was plentiful, but as civilization advanced, and public works of vast scope were undertaken, the demand for slave labor became increasingly great. For this reason it became desirable to increase the mechanical efficiency of the grinding mill, and the obvious way to accomplish this was to change the backward and forward movement to a continuous rotary one.

Just when or by whom this change was first introduced we do not know, but there is absolutely no evidence to indicate

that any form of revolving mill was known to the ancients prior to 300 B. C. According to Varro (116-27 B. C.), revolving millstones were invented by the Volsinians, the inhabitants of one of the chief cities of Etruria, destroyed by Rome about 280 B. C. Cato (232-147 B. C.) mentions in a list of farm implements "one ass mill and one thrusting mill" ("mola asinaria una et trustilis una"). The "thrusting" mill must have been the saddle stone, or something closely equivalent, but any conceivable mill which could be driven by a beast of burden must have been constructed on the revolving principle. In view of the fact that writers before Cato's time nowhere mention anything approaching a revolving mill, and that no relics in either Italy or Greece suggest the existence of such a mill prior to the third century B. C., it seems fairly safe to assume that the application of the principle of rotary motion to flour milling was first made in Italy somewhere between 300 and 250 B. C.

For some three hundred years the "thrusting" mill and the revolving mill ("mola versatilis") flourished side by side in the Roman world, and both types followed the legions in their military conquests; but while the saddle stone undoubtedly lived on far into the Christian era as the household mill, the immense mechanical superiority of the revolving mill gradually established it as the only efficient type wherever grain was ground in large quantities.

THE PRIMITIVE QUERN

The earliest form of the revolving mill, or quern, as it was subsequently called, seems to have been little more than a development of the saddle stone. The lower stone was hollowed in such a way as to resemble a cup, and the upper stone was globular in shape, large enough nearly to fill the cuplike hollow, and possibly fitted with projecting "ears" or a handle of wood. Thus the only essential difference in operation

was that whereas the upper stone of the "thrusting" mill was worked backward and forward, in the revolving mill it was turned round and round. Soon, however, it became apparent that this provided hitherto undreamed-of possibilities for increasing the size of the stones, and for the application of more than one-man power. Some lazy and ingenious grinder, instead of painfully walking round and round his mill, harnessed an ass to the handle, and therewith the first step in power milling had been taken.

It is essential to remember that the revolving mills of the Roman period were by no means all of one type; they varied immensely, not only in size, but also in shape and construction. They were alike only in one essential: the lower or bed stone was stationary, while the upper stone revolved. Sometimes the lower stone was cupshaped and the upper one globular; sometimes it was in the form of a cone, the upper stone being hollowed to fit over it; sometimes both stones were flat, or nearly so, the upper stone revolving on a pivot fixed in the center of the lower one. All these types flourished, as we know from many specimens preserved, side by side. Furthermore, the practice of "dressing" flat stones with grooves, the edges of the grooves doing the grinding while the furrows provided channels whereby the ground meal reached the exterior rim of the stones, unquestionably developed during the early period of revolving hand stones. In the British Museum there is a specimen of an upper millstone from the Anglo-Roman period, about twenty inches in diameter, with its lower face regularly grooved in sections of five furrows each.

The particular significance of this fact is that from the days of the Roman Empire, in the first century or two of the Christian era, to the commercial development of roller milling seventeen hundred years later, there was no fundamental change in the actual milling process. The principle of the revolving stone, the use of flat, grooved stones, and the separation of the prod-

ucts of milling into fine flour, coarse flour and bran, were all perfectly well known to the Romans of Nero's time, and thereafter the mechanical growth of flour milling was almost exclusively concerned with the application of different forms of power to the turning of the millstone.

ROMAN FLOUR GRADES

Regarding the grading of the products of milling, Pliny, who died in the year 79 A. D., provides definite information. "From one modius of the grain," he says, "there should be extracted four sextars of bolted flour, half a modius of white meal, four sextars of coarse meal, and four sextars of bran." That the various products represented recognized differences in commercial value is likewise proved by another statement of Pliny's: "When the prices of grain are moderate, meal sells at forty ases the modius, bolted wheat flour at eight ases more, and bolted flour of winter wheat at sixteen ases more." Bolting was a very early development, used not only to produce a fine flour, but still more to separate the flour from the particles of stone chipped off from the millstone, and also from the sand which was frequently mixed with the grain to facilitate the grinding process. Furthermore, the practice of flour adulteration was by no means uncommon, and the millers of Campania made a special point of mixing chalk with their meal to give it an added whiteness—a fact attested not only by Pliny, but by a decree of the Emperor Augustus authorizing an annual payment for the lease of the hill whence this particular kind of chalk was obtained. Thus, in addition to proving the antiquity of supposedly modern flour grades, Pliny shows that the demand for white flour, and a custom analogous to bleaching, existed nearly two thousand years ago.

IN IMPERIAL ROME

The development of the revolving flour mill, driven either by human labor or by beasts, opened the way for milling operations on a scale previously impossible, and in Rome at the beginning of the Christian era we find three main types of mill: the public mill, managed by the authorities and operated with slave or criminal labor; the household mill, likewise generally operated by slaves, but maintained by the wealthy owners of large private establishments, and, finally, the commercial mill, run as a business enterprise, and employing at any rate a proportion of free laborers.

Most of the numerous references in Roman literature to flour milling are concerned with the public mills, and it was by these that the traditional status of the Roman miller was so degraded. Grinding grain in the public mill was one of the lowest forms of labor, and although there are many recorded instances of poets, philosophers and others of conspicuous intellectual attainments who were driven by poverty to hire themselves out as mill operatives, the stigma attaching to the trade was almost ineradicable. The public mills provided most of the flour for the poorer people of Rome, and likewise for many of the cities throughout the Empire; in general the grain trade was a state monopoly, and the policy of "free bread" was in the end one of the main causes contributing to the collapse of the Roman imperial power.

The household mills on the great estates did not differ materially from the public mills; they were operated largely by slaves, working under an overseer, who either ground the grain brought in by the tenant farmers or bought it from the public warehouses. Taxes and rents were paid very largely in produce, and thus there was a steady flow of grain from the small farms to the granaries of the large property owners and likewise to those of the state. Rome was a very large importer of grain,

bringing in wheat from Greece, Sicily, northern Africa and Asia Minor, but most of this trade was in the hands of the government, and there was not much private grain trading on any extensive scale.

COMMERCIAL MILLING IN ROME

Regarding the commercial flour millers of Rome we unfortunately know little, although there is ample evidence to show that many of the mills scattered throughout the city were privately owned and operated on a business basis. The most important single source of information is the tomb of the miller Eurysaces, discovered in Rome in 1838. Eurysaces apparently lived in the later days of the Republic, and the following description of his tomb is taken from Richard Bennett's "History of Corn Milling."

"The tomb is to be seen near the Porta Maggiore. Upon it is the somewhat defaced inscription: 'Est hoc monimentum Marcii Vergilii Eurysaces pistoris redemptoris apparitoris' ('This is the monument of Marcus Virgilius Eurysaces, miller, buyer of grain, and beadle'). The meaning of the last word has been somewhat disputed, but it is generally agreed to be as here translated; and it indicates that Eurysaces was not only a miller, baker and grain merchant, but held some office in the city, that of steward or inspector, probably over the trade; and was evidently a citizen of position.

"Three large and artistically carved bas-reliefs on the tomb represent various episodes in the busy life of the erstwhile miller and grain merchant. A slave with an account book is receiving sacks of grain; Eurysaces himself is in business conference with three persons, one of whom seems to be a master and the others servants; an ass mill is rapidly grinding, a slave with a whip keeping the animal in motion. The second carving shows the meal being carried to the sieve; a customer

buying and paying for flour; grain being pounded in a mortar; four bakers preparing dough on a table near an oven, as Eurysaces stands by expounding the procedure. In the third bas-relief is depicted the weighing of bread on a huge balance in view of the three personages already mentioned, one of whom may be the praefectus annonae or civic official having supervision over the public bread supply."

A century or so after the time of Eurysaces, we find the Emperor Trajan establishing a "College of Pistors," in other words, an incorporated association of millers and bakers. This took place shortly after the year 100, and by the fourth century this association had become exceedingly important. Much of its growth was due to the gradual disappearance of slave labor in the Roman mills, and the development of water mills, most of them privately operated but under close state control. It is this application of water power to the flour milling process which marks the next great forward step in milling history, not only because it provided a new and much more economical system of operating mills, but because, with the disappearance of slave labor, it took flour milling on an extensive scale out of the hands of the state, and made possible the development of commercial flour milling as we know it today.

3

POWER MILLING

Just as the principle of rotary motion revolutionized the technic of flour milling in the century or two just preceding the Christian era, so the application of power, as opposed to human or beast labor, revolutionized the milling industry in the fifth, sixth and seventh centuries A. D. As long as flour milling remained essentially a matter of hand labor, its control necessarily stayed in the hands either of the state, with its unfailing supply of criminals, or of private individuals rich enough to maintain a large force of slaves. Milling as a business was absolutely dependent on sufficient economy of operation to make it profitable, and this economy could be effected only by reducing the labor cost. The reduction was brought about by the development of the water mill.

THE WATER WHEEL

The origin of the water wheel is shrouded in obscurity, but the important fact to note is that its application to milling, and indeed to any form of practical industry, does not seem to have been made anywhere much before 100 B. C. So far as flour

milling is concerned, this is easily explicable by the parallel fact that the rotating millstone was likewise of relatively late origin. The first authentic reference to a water-driven mill is in an epigram by Antipater of Thessalonica, a Greek poet who flourished about 85 B. C. He bids "the maids who labored at the mill" to cease their toil, for "Ceres has commanded the water-nymphs to perform your task, and these now throw themselves against the wheel, forcing round the axle and with it the heavy millstone." Far more important is the reference by Strabo to a water mill possessed by Mithridates, King of Pontus, which the Romans found at Cabira after the defeat of Mithridates by Pompey in 65 B. C. In the absence of opposing evidence, it may be assumed that the water mill was first developed in Asia Minor, and was adopted by the Romans after their conquests in that part of the ancient world.

The Greek, and presumably the Pontic, water wheel was horizontal, and connected directly with the upper millstone by a shaft passing through a hole in the lower one. In this form the water mill had a very low efficiency, owing to the inevitably slow rate of grinding except on rapid streams, and the real adaptation of water power to flour milling can unhesitatingly be ascribed to the Romans, and quite possibly to the engineer and scientist, Vitruvius. Somewhere between the years 20 and 11 B. C. Vitruvius wrote a detailed description of a grinding mill, apparently a novelty, equipped with a vertical water wheel. The shaft on which this wheel revolved was fitted, inside the mill, with a small toothed wheel ("tympanum dentatum"), which, in turn, engaged with a larger one ("secundum tympanum maius item dentatum") set horizontally. This upper wheel turned the mill, the grain being poured down from above by a suspended hopper and the meal being ejected by the rotation of the millstone.

Here we have all the essentials of flour milling as it was practiced for some eighteen hundred years, the outstanding

features being the vertical water wheel and the gearing. It is to be noted that in this mill the gearing was down, making the millstone revolve less rapidly than the water wheel, probably taking into consideration the strong, swift current of the Tiber, but it was early found that by reversing the relative sizes of the cog wheels a slow current could be made to drive a mill rapidly.

THE ROMAN WATER MILL

Curiously enough, the invention of a really efficient water-driven mill seems to have had very little effect on flour milling in Rome for nearly four hundred years. The explanation lies in the fact that slave and criminal labor remained abundant, and that the state was unwilling to give up its virtual monopoly of the grain and flour trade. Late in the fourth century, however, the practical abolition of slavery gave a new impetus for the development of labor-economizing machinery, and in the year 398 an edict of the Emperor Honorius imposed a fine of five pounds in gold on any one who should "be impudent enough to dare to appropriate any of the water driving the mills which provide the venerable institution of state-supplied food to the city." This indicates that the source of water power for most of the Roman mills at that period was not the Tiber, but some special watercourse, presumably the old aqueduct of Trajan, which brought the water from Lake Sabbatina twenty-two miles to the trans-Tiber district of Mount Janiculum. It is this hill of Janiculum which seems to have constituted the first real milling district, and there are references to the mills of Janiculum in the writings of various late Roman authors.

The fact that the water supply of these mills could be cut off at will by an enemy outside the city led to another important development in the application of power to milling. In the year 536 the Goths, who were besieging Rome, actually did cut off this supply of water, and Belisarius, the Roman commander,

devised a mill to float on the Tiber. As Procopius, nearly a contemporary, writes: "Below the bridge across the Tiber, which arches to the walls of Janiculum, Belisarius extended ropes, well fastened across the river from bank to bank. To these he affixed two boats of equal size, two feet apart at the spot where the current flowed with the greatest rapidity under the arches; and placing large millstones in one of the boats, he suspended the machines by which they were turned in the water space between."

INDUSTRIAL ORGANIZATION

Reference has already been made to the "College of Pistors," or incorporated association of millers and bakers, founded by Trajan about the year 100 A. D. It was not until the fourth century that this organization seems to have become really important, but after the middle of the fourth century laws concerning it were numerous. Thus the development of the first millers' association coincides with the growth of the water mill, illustrating the point already made that commercial flour milling was dependent on the employment of a power supply to some extent independent of slave, criminal or hired labor.

A few sections from the summary of these laws prepared by the French economist, Le Mare, are of special interest. "Those in the trade were necessarily attached to the college, without power of leaving it under any pretext whatsoever. Their sons were not free to leave it to take up other trades, and those who married their daughters were compelled to follow the same profession. As soon as a son was born to a pistor (miller and baker), the infant was counted as a member of the college; but until he was twenty-one years of age he was not compelled to work at the trade, and the association was bound to maintain, up to that time, a man in his place.

"All the grain from the public granaries was distributed to

the pistors at their places of business. They paid nothing for a certain quantity, which they had to make into bread for free distribution to the people. As to the rest, they paid the price decided by the magistrates, which would fix the price of the bread to be sold. As all this grain belonged to the state, the greater part of it being the tribute imposed on the provinces, it was easy to make this fixed price. Whatever grain afterwards came into the market was always theirs, sold at a fair rate. It was stringently prohibited to sell or deliver any grain from the public granaries to any except the pistors, and the pistors themselves were required to render full account to the magistrates of all grain received by them."

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THE FEUDAL MILL

This chapter is based on the fundamental conception of feudalism. In each country, theoretically at least, all rights save those of the church emanated from the king. To him directly the great nobles, the princes, dukes, counts and barons, owed personal service, and in return received from him rights over restricted territories closely analogous to the king's own. The great nobles, in turn, received like service from and conferred similar rights on the lesser nobility and the free landholders; the mass of the people were mere tenants, closely bound to the soil. Side by side with this feudal organization, and often in sharp conflict with it, stood the church, the higher and lower clergy having very nearly the same relations to one another as the greater and lesser nobility.

To some extent, from the very beginning, the larger cities stood outside of this double system. In most cases they were not directly subject to any one great lord, and from the earliest medieval times they were regarded as peculiarly under the protection of the kings. They had a certain degree of self-government, together with special rights and privileges which were jealously guarded.

THE TENANT MILLER

It was in a society thus organized that flour milling was carried on for more than a thousand years, practically speaking without one material change or improvement of importance. The reason for this industrial and mechanical stagnation is to be found in the status of the miller himself. For ten centuries hardly a miller in Europe owned his own mill. Land and building alike were the property of the feudal or ecclesiastical lord, or of the municipal corporation; the king owned mills; the dukes and counts and barons owned them; the abbeys and priories owned them; the cities owned them; everybody might own a mill except the miller. He was at best a tenant, reasonably assured of his continued right of residence and labor, and of passing along his business to his son and his son's son, provided he complied in every detail with the requirements of his landlord, but virtually denied any right to hold a real interest in the property he managed, or even to increase by industry and shrewd judgment his own profits therefrom.

From the mechanical standpoint there was practically no improvement in flour milling from the late Roman days to the eighteenth century, save in one detail: the introduction of the windmill. Evidence regarding the origin of the windmill is vague and more or less contradictory, but apparently it was introduced into western Europe from Asia Minor, where the crusaders had found it in operation on the waterless plains of Syria. In any case, the first trustworthy reference to windmills anywhere in western Europe points to a date not earlier than the close of the twelfth century. By 1250, however, they were reasonably common, and in the following hundred years their number increased enormously. This development, of course, had nothing whatever to do with the actual process of milling, and merely provided a new source of power. Within the mill itself the machinery was essentially like that described by

Vitruvius, and while the remarkable mechanical ingenuity which led to notable scientific achievements in other fields was sometimes applied to the problem of grinding grain, the inventions and discoveries were utterly disregarded by the millers themselves.

ECONOMIC INERTIA

The reason for this was the hopeless economic position of the miller, and particularly of the miller outside of the cities. A paragraph from Richard Bennett gives the picture vividly and with substantial accuracy: "Let us glance at the master-miller of the past—the bond-servant of feudal lords, the slave of legislative oppression, the skilled artisan toiling for slight gain, the object of popular suspicion and gibe, the butt of poetic innuendo and witty satire. Watch him year in, year out, bound rigidly down to grind at one unvarying rate of toll corn, whether grain be cheap or dear; to labor by rule of thumb; to gaze at the monotonous whirl of water wheel or sail yard, and hear the ceaseless whir of the stones, without an atom of speculative interest whether any one process were capable of improvement; to know that, if his custom from astricted tenants were secure, its value to him had been carefully calculated beforehand in the estimate of his rental by his landlord, and there was no chance by any expenditure of energy or skill of increasing it, not even to cover long-impending repairs or sudden disaster due to fire or flood."

Not only was the medieval miller's mechanical ingenuity deadened by the fact that he had no incentive to improve his processes, but his business instincts were atrophied by the practically universal custom of "milling soke." Each mill being the property of the manorial lord, it was obviously to his advantage to stifle competition by preventing the erection of rival mills, and to compel all his tenants to have their grain ground

at the one mill from which he received direct rental. The "soke" (the word originally meant privilege or liberty) was nowhere established by statute law, but it early became one of the inalienable rights of feudalism. Each mill, under this custom, had a complete monopoly within its own limited district; its customers could never take their grain elsewhere to be ground, and no competing mill could be set up on the same estate; conversely, the miller was absolutely prevented from extending his trade beyond the limits fixed by his privilege. So long as feudalism continued, this "milling soke" remained at once the safeguard and the bane of the milling industry, destroying initiative and reducing flour milling to the level of common labor.

THE GUILDS

Even in the Middle Ages, however, there were signs of better things to come. The large cities, as has been said, stood to a considerable degree outside of the feudal organization, and in the cities the members of the leading trades, supported by municipal sanction, often leagued themselves together in associations or guilds. As a rule, the millers were conspicuous for their failure to form such guilds, the reason being that most of the mills were in the country, adjacent to the grain fields, whereas the bakers were most active in the cities, where the bakers' guilds early became important trade and social organizations. There was a millers' guild formed in Paris in 1270 by Etienne Boileau, prefect of the city, but its chief purpose seems to have been the formulation of municipal regulations to control the industry, and particularly to regulate the operation of the floating mills on the Seine.

In England the only important millers' guild recorded is the one at York, and this, like the Paris guild, seems to have been mainly concerned with the formulation of municipal regula-

tions. The maintenance of civic supervision over the trade was regarded as a matter of public concern, and offenses against the effectiveness of this supervision were punished by fines which were appropriated to the use of the city. The rules of the guild were, to all intents and purposes, city ordinances, confirmed by the lord mayor, and it is worth noting that one of these rules imposed a fine of ten shillings on any citizen of York who "shall buy or cause to be bought any manner of corn of any person or persons in the country to be brought into this city grinded into meal, to the intent to defraud the lord mayor of this city for the time being of his due for the same." The guild, in other words, had secured a monopoly of flour milling in York, and it was a public offense for any one to bring in flour from outside.

Far as flour milling lagged behind many other forms of industry, there was in these associations of city millers the germ of the milling industry of today. From the beginning of the Middle Ages down to the first part of the nineteenth century, the country miller throughout Europe was, in general, a mere tenant, at once protected and restricted by immemorial custom, and never dreaming of the possibility of extending his business. With the city mills it was different. The populations of the great centers were steadily increasing, and more and larger mills had to be constructed to grind flour for them. Little by little the grain trade, once exclusively in the hands of the landowners, became specialized; the Corn Exchange in London was built in 1747, and the date may be taken as representing approximately the time when grain trading in the modern sense really began throughout western Europe. Individual millers in the large cities, gradually set free from stringent municipal regulation, acquired ownership of their mills and discovered the advantages of increased capacity and output; they had, moreover, the incentive of competition, still denied to most of their country colleagues.

5

THE ERA OF STEAM

Two things, until nearly the close of the eighteenth century, operated to hold the milling industry in check. Transportation was so little developed that the local mill had an immense advantage over its distant competitor; the radius within which any miller could profitably ship his flour was exceedingly small. Thus the larger mills of the eighteenth century did practically nothing except a local city trade, and there was nothing to shake the security of the small country miller. The second obstacle was the limitation of power. The available amount of water power was everywhere restricted by nature, and it was further curtailed by immensely complicated legal questions of rights and privileges. Windmills were at best uncertain, and the power was adapted to use only in small plants. The patenting of the steam engine by James Watt in 1769, and the application of the steam engine to the locomotive by George Stephenson in 1829, are the dates which mark the real beginnings of modern flour milling. With steam power a flour mill of almost any size could be built and operated anywhere; with rail transportation the products of a mill

could be shipped on a competitive basis wherever a market could be found.

It was Watt himself who was largely responsible for the first practical application of steam power to flour milling. In 1783 a company was formed in London to build a large flour mill with power provided by engines built by Watt and his partner, Boulton; a considerable part of the stock in this company was held by Watt and Boulton themselves. The mill was built on the bank of the Thames near the southeast end of Blackfriars' Bridge, and began operation in 1786. It was equipped with twenty pairs of millstones, each four and a half feet in diameter, and each pair capable of grinding ten bushels of wheat an hour. The two engines supplying the power were each of fifty horsepower capacity. One important innovation, provided by John Rennie, a young Scotch engineer called in by Watt, was the substitution of metal cogs, shafts and bearings for the clumsy wooden mechanism then universally in use. This detail, apparently small in itself, was destined to have enormously important consequences in the transition from stone to roller milling which was to take place two or three generations later.

THE ALBION MILLS

The new plant, known as the Albion Mills, was promptly and conspicuously successful, despite the open hostility of all the other London millers. Its flour was of excellent quality, it had the largest capacity of any flour mill then in existence, and, in spite of the inordinately high cost of fuel, it was able to sell its flour at a relatively low price, its large output enabling it to reduce its profits per sack to a small figure and still make money. Interesting evidence on this point is afforded by a report made by Lord Sheffield in 1800 on the average profits of flour milling. For the twelve years from 1774 to 1785 the average profit of the

London millers on a sack of flour was five shillings sixpence halfpenny; from 1786 to 1791, while the Albion Mills were running, it was reduced to two shillings tenpence halfpenny; beginning with 1791, after the Albion Mills had been destroyed by fire, the profit per sack advanced rapidly, and for the five years from 1795 to 1799 it was eight shillings eightpence halfpenny.

It is also interesting to note the character of the Albion Mills' products, as reported by Samuel Wyatt, manager of the plant, to a parliamentary investigating committee. Reduced to a decimal basis, Mr. Wyatt's figures show that the mill made 78.8 pounds of flour out of a hundred pounds of wheat, divided as follows: fine households, 52.7 pounds; seconds, 15.7; thirds, 6.6; fourths, 8.8. The feed was divided into 5.2 pounds of fine pollard, 2 of second pollard, 1.5 of third pollard, 6.8 of house pollard, and .9 of bran.

It is generally believed that the fire which destroyed the Albion Mills on March 8, 1791, was of incendiary origin, and the plant was never rebuilt; the principle, however, had been successfully demonstrated, and it was not long before steam-driven mills began to appear at various places both in England and on the Continent. In practically every case these new mills were located in or near large cities; the problem of transporting flour was still unsolved, and while such plants as the Albion Mills did a considerable business in making shipments by water,—the Albion Mills shipped their low grades to Liverpool and Newcastle for the manufacture of ship's biscuit,—anything like a really extended trade in flour awaited the coming of the railroad.

RAIL TRANSPORTATION

The period of waiting was not long. The Stockton & Darlington railroad line was opened on September 27, 1825, with Stephenson himself driving the engine. In 1828 France and

Austria opened their first railroad lines; Germany, Belgium, Russia, Italy and Holland followed within a few years. The fifteen years from 1835 to 1850 formed a period of immense activity in railroad building throughout Europe and the United States, and by the close of that period the problem of transporting flour had been solved. With steam enabling the miller to escape the limitations of water power, and to increase the capacity of his mill to the full extent of his selling ability, and with railroads to carry his products wherever he could find a market for them, the last barrier in the way of the development of flour milling as a great industry had been broken down. Furthermore, rail transportation facilitated increased milling capacity at centers by vastly enlarging the area from which the miller could draw his wheat. The small country miller was at last beginning to be dislodged from the position he had held for centuries, and the way was clear for the development of the merchant flour milling of today.

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ROLLER MILLING

There remained one great step still to be taken. We have seen that the actual milling process of 1800 was very little altered from that of the Romans in the fourth century. The grain was still ground between millstones, and while the best millers were very particular in their selection of stones, and stone dressing had developed into a special art, there is no reason to believe that they had made any material advance in either respect over the practice of the Roman pistors. There had been many experiments with machinery for the bolting of flour, including the use of cylindrical reels, but here again the methods employed were essentially the same as those which had persisted for centuries. There had, however, been repeated attempts, less by millers than by experimental engineers, to devise substitutes for the clumsy millstones, and as far back as 1588 or thereabouts Augustino Ramelli, a military engineer in the service of Henry III of France, published a design for a flour mill employing a corrugated iron roller. Bocklerum's "Theatrum Machinarum," published in 1662, contains a design for a roller mill, the single roll revolving against a fixed base extending through a quarter of a circle. Hazlitt describes a

sort of roller mill in his book on husbandry, published in 1651, and Isaac Wilkinson actually took out a patent for a roller mill, using "a new sort of cast metallick rolls," in 1758. As applied to practical flour milling, however, nothing was done with the roller process until the second quarter of the nineteenth century.

The reason for the late development of roller milling was not, as is generally assumed, the failure of milling engineers to recognize the potential superiority of rolls over millstones, but the purely mechanical one of inadequate power transmission. Water or wind power might turn a millstone four feet in diameter at a sufficient rate of speed, but without either elaborate gearing or a satisfactory system of rope, belt or chain drive they could not develop enough speed to secure satisfactory results with a roller having a diameter of only a few inches. We have seen that until 1785, when John Rennie introduced metal gears in the equipment of the Albion Mills, gears and shafting were almost invariably made of wood, and hence were clumsy, inefficient and liable to wear and breakage. Rope and belt drives, although understood in principle for centuries, were not developed practically until the nineteenth century; the real use of rope transmission dates back only to about 1856. The early experiments with grinding rolls were chiefly concerned with portable, hand-propelled machines; the introduction of roller milling on any large scale necessarily awaited the development of a form of power capable of driving the rolls at the requisite rate of speed.

GRADUAL REDUCTION MILLING

The steam engine met this first requirement, and thus, as steam flour mills began to make their appearance in England and on the Continent, in the first quarter of the nineteenth century, we find milling engineers everywhere turning to the problem of

finding more efficient substitutes for the millstones. A roller mill patented in 1775 by George Rawlinson, in which "the grain is first crushed by rollers combined with the hopper, and the crushed material is conducted thence over a fine sieve, which separates from it the dust and seeds before the material reaches the stones," provided most of the essentials both of "high" as distinct from "low" grinding and of the roller process, but, as has been said, the proper kind of power was lacking, and it was not until nearly fifty years later that efforts were made to introduce rolls into flour mills on any large scale. These first attempts, made about 1820 by Collier in Paris, Bollinger in Vienna, and Helfenberger in Switzerland, were all unsuccessful.

Meanwhile, however, the principle of "high" grinding, the reduction of the grain by successive partial grindings instead of by a single operation, was being extensively developed, above all in Austria, the work being done, of course, entirely by millstones. There was nothing new about this system; gradual reduction milling had been in use to some extent in France certainly since the middle of the eighteenth century. In 1764 the French government sent a miller named Buquet, who had been in charge of the mills of the General Hospital at Paris, to demonstrate the value of regrinding to the country millers of France, and by the time of the French Revolution a crude sort of gradual reduction milling seems to have been fairly common, at any rate among the French millers. The Austrian mills, however, in the first thirty years of the nineteenth century, were the real demonstrators of the commercial superiority of "high" over "low" grinding, and it was from the work of these stone mills that Austrian flour won its initial reputation.

The significance of this change in milling methods, the first one of real importance to appear in more than fifteen centuries, is by no means generally realized. Essentially, the purpose of all flour milling is to effect as nearly complete a separation as

possible between the kernel or berry of the wheat and its rough outer covering. The single grinding made this separation crudely; some of the bran, broken in the grinding process, found its way into the flour, and some of the flour was inevitably carried off with the roughage as waste. Gradual reduction meant that after each grinding the middlings, as they later were called, were sifted to extract the pure flour, the remainder being then reground, until, by the time the process was complete, the separation was reasonably thorough. Thus the process not only gave a much finer, whiter flour than the old method of single grinding, but also produced considerably more flour from every bushel of wheat, owing to the elimination of waste. This economical feature was an important contributing cause to the success of Austrian flour milling in the first quarter of the nineteenth century.

THE SULZBERGER METHOD

This was the state of things when, in 1830, a Swiss named Miller succeeded in organizing a company to erect a new flour mill, on plans of his own designing, at Frauenfeld. Miller had lived for some years in Poland, and is said to have secured the necessary financial backing for his venture on the strength of his glowing tales of the successful operation of his mills in Warsaw—mills which seem to have existed only in his own imagination. At any rate, his mill was built, five stories high, with rolls on every floor, the breaks being on the fifth story and the finishing rolls on the first. The mill was started in 1833, but it was a complete failure. Miller, discredited, vanished, but the company, finding a white elephant on its hands, determined to make one more attempt. The directors called in a Swiss engineer, Jacob Sulzberger, who completely remodeled the plant, placing all the rolls on the first floor, and arranging them with two pairs in a single frame, one pair above the other. The

success of the reconstructed plant was as complete as the failure of the original one had been.

Encouraged by this success the Frauenfeld company promptly went into the business of building and equipping mills on the Sulzberger model, and between 1835 and 1846 it built roller mills at Kriens, Mayence, Melegnano, Venice, Munich, Leipzig, Stettin, Pesth and elsewhere. The contract under which these mills were built was very stringent, and no person not connected with the mill was permitted to inspect the machinery. This effort to keep the roller process a trade secret was, in the end, disastrous to the Frauenfeld company, for the machinery was so complicated that there was never an adequate supply of men trained to operate it, and although the Frauenfeld company instituted a training school for roller millers at its own works, most of the plants which it constructed fell into disrepute by reason of the lack of competent operatives.

PROGRESS IN HUNGARY

The outstanding exception was the mill at Pesth. This mill was established in 1839, one of the chief proprietors being Count Stefan Szechenyi, famous in Hungarian history. Peculiarly favored by the exceptionally fine quality of the Theiss "steel" wheat, and by admirable business management, the Pesth Walzmühle (Roller Mill) soon became the most famous flour mill in the world. For over twenty years it used rollers only in conjunction with stones, the rolls effecting the first breaks and the stones the final reductions. In 1863, however, the stones were replaced by rolls, and in 1867, owing to the enormous increase in its business, the plant was greatly enlarged.

Despite the recognized success of the Pesth mill, the extension of roller milling throughout Europe, and even in Hungary itself, was exceedingly slow, largely because the millers were

unfamiliar with the machinery and, consequently, afraid of it. In the sixties a number of mills were partially equipped with rolls, many of them on a system devised by G. A. Buchholz; the first English mill to discard stones entirely was that of Messrs. Radford & Sons at Liverpool, which was remodeled in 1870. The quality of the best flour produced by the Radford mill was so fine that it readily commanded a price of from fifteen to twenty shillings a sack above that of the stone mills, and the object lesson was too clear to be missed. Railroad and steamship transportation was rapidly developing, and freight charges were correspondingly diminishing, with the result that competition in flour was developing on a scale previously undreamed of. Roller mills like those at Pesth and Liverpool were distributing their products over wide areas, and for the first time in history millers everywhere had a real incentive to improve their milling methods.

By 1875 two things were apparent throughout Europe: first, that flour produced by a combination of gradual reduction and the use of rolls was vastly superior to the product of the stone mills, and, second, that flour ground from hard wheat had much greater strength than the soft wheat product. Hungary, with its vast supplies of "steel" wheat, exceptionally rich in protein and gluten, was beginning to do an enormous export business in flour; it owed something to its early adoption of roller milling, much to its wheat, and most of all to the scientific perfection of the system of gradual reduction milling, from which the "Hungarian process" became the generic term the world over for the new milling method. In 1867 there were about a hundred and fifty steam flour mills in Hungary; in 1895 there were 1,728, of which four hundred and eighty-eight were listed in the census as "large." It is small wonder that flour formed by far the largest single item of Hungary's export trade.

Most of the other countries of Europe, exclusive of Russia, produced mainly soft wheat, and the enormous demand for the

products of the Hungarian mills led the millers elsewhere to look abroad for possible supplies of wheat to rival that of the Tisza valley. Hungary itself exported great quantities of hard wheat, and Russia, with a vast surplus of both hard and soft wheat, became in the last decades of the nineteenth century the foremost wheat exporting nation in the world. In France, Germany, Switzerland and Italy, and most of all in the United Kingdom, the leading millers became expert in mixing different varieties of wheat, and as wheat growing expanded in the United States, Canada, Argentina, Australia and India, the millers of Europe drew increasingly large proportions of their raw material from lands other than their own.

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MILLING IN AMERICA

It was apparent, however, that any nation which had a surplus of desirable wheat for export could still more profitably export the flour manufactured therefrom, and this leads directly to the development of the milling industry in the United States and the other great wheat producing countries outside of Europe. From early colonial days until the period of the Civil War, flour milling in the United States had closely followed the English model. Practically all the wheat grown was of the soft winter variety, and as the wheat belt, beginning in Virginia and Pennsylvania, had extended westward through Ohio, Indiana and Illinois into Missouri, flour milling went along with it. Richmond, Virginia, was the first real milling center; in the twenties and thirties the "flour city" was Rochester, New York; in the fifties and sixties the milling leadership belonged to St. Louis, Missouri. Roller milling was unknown, and the soft wheat everywhere used did not appear to call for the introduction of the "Hungarian process" of gradual reduction.

The great transformation came in the years following the Civil War. Wheat had been grown to some extent in Minnesota,

and a few small mills had clustered about the Falls of St. Anthony, attracted by the ample water power, the first one having been set up on the government reservation as early as 1828; but hard spring wheat, the only kind which could then be successfully grown in the Northwest, defied the familiar milling methods, and such of the flour ground in the Minneapolis mills as was not consumed locally was shipped down the Mississippi to St. Louis, to lose its identity in blends with the soft wheat flour of Missouri and Illinois.

THE MIDDLINGS PURIFIER

It was in 1870 that Edmund N. La Croix, a Frenchman, introduced in the Christian mill in Minneapolis what the Department of Agriculture report termed "a system of high grinding in operation in his native country." To a large extent this system was simply the gradual reduction method which had long been known in France, Switzerland, Austria and Hungary, but it had one distinctive feature, the middlings purifier. There had been much experimenting in Europe with machinery for separating the flour from the ground middlings, so that the middlings might be subjected to further grinding, and a purifier resembling the one built by La Croix in 1870 had been patented in France by Perrigault in 1860. It was to La Croix, however, that the middlings purifier owed its introduction in America and its first application to practical milling on a large scale, and La Croix's work was soon destined to revolutionize the milling development of the United States. That the design of the purifier was stolen by some one else, with vast profits to the Smith Middlings Purifier Company, and broken-hearted poverty for La Croix, constituted one of the most dramatic chapters of injustice in the whole history of milling.

SPRING WHEAT MILLING

The "Hungarian process" and the middlings purifier, both introduced by La Croix, entirely changed the position of hard spring wheat flour. The product of the Minneapolis mills suddenly was as much in demand in America as that of the mills of Hungary in Europe, and although stone grinding continued for another ten years, there was an extraordinary increase in mill building, not only in Minneapolis itself but at other points in the spring wheat territory. In 1880 there were said to be six hundred and sixty-seven pairs of stones running in Minneapolis alone; mills like those at Hastings, Northfield and Dundas were doing a remarkable business. In 1877 William H. Dunwoody, then associated in the milling business with Governor C. C. Washburn, went to England for the purpose of introducing Minnesota spring wheat flour on the British market, and within a few years hard wheat flour from Minneapolis was giving Hungarian flour its first real battle in Europe for the world's supremacy.

THE ROLLER PROCESS

The next step was the substitution of rolls for millstones. In 1874 George H. Christian & Company, of Minneapolis, had ordered a set of rolls for experimental purposes, and in 1878 Governor Washburn, who had seen roller mills in operation abroad, set up a hundred-barrel experimental mill at one end of the Washburn C plant, equipped with rolls supplied by William D. Gray, milling engineer for Edward P. Allis & Company. So little faith still was placed in the roller process that when the Washburn A mill was rebuilt after the explosion of May, 1878, it was entirely equipped with stones. In 1880, however, Governor Washburn determined to re-equip his A mill on the Hungarian model, and sent William de la

Barre, famous as a construction engineer and water power expert, to Budapest to investigate the system. Mr. de la Barre, who had been interested in roller milling ever since the Philadelphia Centennial Exposition in 1876, did more than any other one man to establish the new process on a successful commercial basis in America. It was in that same year, 1880, according to the census report, that the mills of C. A. Pillsbury & Company were fitted up with a complete system "in which the middlings from the several reductions are passed through purifiers, and then are reduced to flour by successive reductions on smooth iron or porcelain rolls." After 1880 practically all the new flour mills built in the United States were equipped exclusively with rolls, and most of the old ones had been remodeled for roller milling by 1890. It was the introduction of roller milling and the gradual reduction process which gave birth to the term "patent" flour, now used merely to designate the best grades, irrespective of the milling system used.

The two decades following 1880 formed the great period of expansion for the hard spring wheat mills of the Northwest. The flour output of Minneapolis, which in 1878 was less than a million barrels, was over fifteen millions in 1900; in that same year the direct exports of the Minneapolis mills reached their maximum, 4,702,485 barrels, whereas twenty-five years earlier the export flour trade had been practically nonexistent. In 1870, according to the census, Minnesota had less than a thousand persons engaged in the milling industry, the foremost milling states being Pennsylvania and New York. In 1880 Minnesota stood in seventh place among the milling states; in 1890 it ranked fifth, and by 1900 it was far and away the first. Beginning about 1900, however, two new forces made themselves felt in the development of America's milling history. One of these was the successful evolution of hard winter wheat milling; the other was the rapid growth of flour milling in Canada.

THE SOUTHWEST AND CANADA

Until 1900 or thereabouts, the spring wheat mills of the United States had enjoyed a virtual monopoly of the flour export trade, the foreign demand being almost entirely for hard wheat flour, and had also been able to sell their flour in the domestic markets at prices held down only by competition among themselves. The millers in the winter wheat belt found themselves at a serious disadvantage, but in Kansas, where a colony of Mennonites had introduced very successfully a variety of hard red winter wheat, was found the necessary basis for competition with spring wheat flour. Gradually, as the result of energetic and farseeing work on the part of the millers, aided by the state agricultural authorities, the Kansas farmers turned from soft to hard winter wheat. For years hard winter wheat flour had an uphill fight to establish itself, in the face of the reputation of the spring wheat flour from the Northwest, but it had in its favor the fact that hard winter wheat almost always sold at a discount below spring, and the two decades following 1900 saw an expansion in hard winter wheat milling comparable to that of the Northwest in the eighties and nineties.

Facing the aggressive and steadily increasing competition of the hard winter wheat mills on the south, the spring wheat millers likewise found themselves confronted by a new competition from the north. Canada, with its enormous prairies ideally suited to spring wheat cultivation, began in the nineties to build up a milling industry equipped to compete for a share of the export flour trade of the continent, and after 1900 the volume of its flour exports increased at a rapid rate. Caught, as it were, between two fires, the spring wheat millers held their own, and even increased their capacity and output to some extent between 1900 and 1920, but their progress was inevitably slow in comparison with the amazing record of the preceding two decades. Meanwhile, the soft winter wheat millers of the

central states and elsewhere had found a new and very important outlet for their products in the rapidly growing biscuit and cracker trade, and also in the greatly increased demand for pastry flour. While there was no startling increase in the per capita consumption, the growing population of the country led to a steady gain in all types of flour milling.

BAKERS AND FEED DEALERS

Meanwhile, the general character of the American flour trade was materially changing. The most important influence on it was the enormous increase in the commercial baking industry, largely at the expense of home baking. The 1900 census estimated the total value of bakery products at $175,369,000; in 1920 the figure was $1,151,896,000. This meant a great increase in consolidated flour buying, a diminishing value for flour brands solidly established by general advertising and many years of reputation in the household trade, and flour sales made at a very close profit margin, or at no profit at all. On the whole, and despite frequent allegations to the contrary, the phenomenal growth of commercial baking after 1900 seems to have increased the per capita flour consumption, but it has likewise involved the flour mills in many and serious difficulties regarding their selling activities, owing to its creation of a market dominated by the flour buyers. While no accurate estimates are possible, it seems fairly safe to say that by 1923 from 70 to 75 per cent of the flour entering into domestic consumption in the United States passed through the hands of commercial bakers.

With flour prices thus held down by sharp competition and by consolidated buying, the profits of milling became more and more dependent on the market for its byproducts. In the eighties the mills regarded the bran and other "refuse" separated out from the flour as of so little value that it was

frequently dumped into the millrace or burned for fuel. The rapid growth of the live stock and dairy industries, however, with the curtailment of pasturage, gave a new importance to animal feedstuffs with relatively high protein content, and the demand for bran and shorts (or middlings) and low grade flour rapidly increased. In the 1920 census the production of bran and middlings as byproducts of flour milling was estimated at 4,817,000 tons, having a total value of $214,196,000. This, by actual weight, represented 27 per cent of the total amount of wheat ground, the remaining 73 per cent being converted into flour. The distribution of feed became a very extensive and highly specialized business, most of the millers selling their byproduct feed to jobbers, who, in turn, sold it to the farmers.

THE WORLD WAR AND AFTER

The normal development of flour milling was, of course, sharply interrupted by the upheaval of the World War. From the moment when the onrushing German armies were first checked at the Marne, it was apparent that victory was to be a matter of endurance and, very largely, of food supply. Everywhere it became essential to "save the wheat," and flour milling was forced into strange paths in order to eke out the available wheat supply through the use of substitutes. Moreover, throughout the belligerent nations the war meant a growing shortage of man power for industry, and thus imports of flour by the allies from America, Argentina and Australia increased enormously. Canada's flour exports more than doubled between 1914 and 1919, as did those of the United States; in 1919 Argentina exported five times as much flour as in 1914; Australia's increase was 50 per cent.

After 1919 there was a marked reaction; millions of men in Europe were returning to industrial activity, and the belligerent nations, most of them on the verge of bankruptcy, uniformly

adopted the policy of increasing their domestic flour output, and of importing as much wheat and as little flour as possible. Throughout Europe the next three years witnessed a great increase in flour milling activity, and the exports from the principal wheat producing nations correspondingly diminished, leaving the millers, handicapped by national overcapacity in flour production, to fight for their share of the domestic and export business even more keenly than in the years just preceding the World War. The year 1923, however, saw a distinct revival of flour export activity for both the United States and Canada, and particularly for the latter, owing, above all, to the remarkable growth of trade with the Orient.

The tendency to reduce the number of flour mills in the United States, while increasing the capacity and output of the larger units, has been particularly marked in the post-war years. Comparing the census reports for 1909 and 1921, the total number of flour mills decreased from 7,342 to 6,348, while the number of mills producing annually 100,000 or more bbls of flour increased from 198 to 289. In its earlier days flour milling developed in the United States, quite after the medieval pattern, on the theory that the mill should be close to the wheat fields; the war years showed that economy meant placing the mill where it could secure the benefits of low bulk rates on the long haul for wheat, and enjoy the advantages of a short haul for its flour to the centers of consumption. Thus Buffalo, able to use both Canadian and United States wheat shipped by lake, increased its flour production from about 1,000,000 bbls of flour in 1900 to more than 7,000,000 in 1916, becoming easily the second milling center in the country.

This is not the place for a detailed statistical analysis of the American milling industry, but a few figures for the calendar year 1923 will serve to show its general scope and character. The country's total flour output for the year was about 125,750,000 bbls; the aggregate potential capacity of the active mills, based

on 300 running days of 24 hours each, was perhaps two and a half times that amount. About 85 per cent of the total flour production was accounted for by the operation of approximately 1,100 mills, including all of the larger plants; the remaining 15 per cent was produced by perhaps 4,000 smaller mills, many of them operating on a custom basis or only a small part of the time. Minneapolis still retained the lead as a milling center, with a total flour production for the year of 13,488,000 bbls, 5,000,000 less than the high point reached in 1916. Buffalo stood second, with a flour production of 6,468,000 bbls, and Kansas City third, with 4,887,000, marking its record year. Portland, Oregon, came fourth, followed closely by St. Louis, Seattle, New York, Toledo, Tacoma, St. Joseph and Chicago, in that order. Domestic wheat flour consumption for the year was estimated at about 107,000,000 bbls, or approximately 190 lbs per capita. Flour exports for the year amounted to 16,310,000 bbls; flour imports, all from Canada, to 268,000. The general distribution of flour exports in 1923 was as follows: to the United Kingdom, 1,648,000 bbls; Netherlands, 1,893,000; Germany, 1,248,000; Norway, Sweden, Denmark and Finland, 1,286,000; Mediterranean Europe, 715,000; other Europe, 548,000; Cuba, 1,090,000; other West Indies, 903,000; Mexico and Central America, 1,003,000; other North America, 120,000; South America, 882,000; China, Hongkong and Kwantung, 4,111,000; other Asia and Oceania, 341,000; Africa, 527,000.

MILLING AS AN INDUSTRY

The intense competition which has existed among the flour mills of the United States throughout the past 40 years epitomizes the history of the milling industry the world over since 1850. Until that time, from the earliest beginnings of civilization, flour milling had been probably the least competitive of all the important industries. Primitive man ground grain solely

for himself and his family; in the days of the saddle stone, milling remained essentially a household affair; the Roman pistors worked as semipublic functionaries, grinding state grain largely to enable the government to provide the people with free bread; the medieval miller found his trade at once guaranteed and restricted by feudal custom; and even in the eighteenth and early nineteenth centuries small capacity and lack of transportation facilities prevented extensive competition between flour mills.

The 20 or 30 years following 1850 made greater changes in milling than had been witnessed by all the centuries before. Gradual reduction milling and the use of rolls made possible the grinding of hard wheat, and produced differences in flour quality which were immediately reflected in flour prices. This, in turn, set an entirely new value on established flour brands, and made the merchandising of flour quite as important a part of the milling business as its manufacture. Finally, the enormous development of transportation facilities, both by land and by sea, in the past 75 years has opened all the markets of the world to every miller equipped to do an extended business.

This complete transformation in the conditions affecting the milling industry has shown its influence above all in the commercial organization of the milling companies themselves. All over the world, in Europe as well as in the newer countries of the Western Hemisphere and in Australia, competition has favored the growth of great milling corporations at the expense of small concerns. The small mill with its local business still has its place, but every year sees the number decreasing, whereas each year the consolidation of mills into groups, and the expansion of the leading companies through new construction, become more pronounced. Out of the saddle stone of the Old Testament has come the 14,000-bbl flour mill of today, but the change from the primitive equipment of 25 centuries ago to the superb machinery of the modern mill is less remarkable

than the transformation of the household slave into the head of a vast corporation, extending his company's business into every land where bread is the staff of life.

A FLOUR MILL OF TODAY

It would be impossible here to enter into any discussion of the technical aspects of modern flour milling, but, as a conclusion to this outline of milling history, a brief description of the largest flour mill in the world, the Pillsbury A mill in Minneapolis, from the standpoint, not of the miller or milling engineer, but from that of the casual visitor, will serve to give a picture of milling as it is carried on today.

When one stands with a visitor to Minneapolis on the Third Avenue bridge, and, pointing out the Pillsbury A mill, tells him that it is the largest flour mill in the world, he looks surprised, disappointed perhaps. He has seen cotton and woolen mills in the East which held no record for size, and yet which were far more impressive in sheer bulk. He has seen the acres upon acres of the steel mills at Pittsburgh or Gary, or the immense plants in which automobiles are made. The largest flour mill in the world ought to be something gigantic, overpowering; it seems incredible that this solid, square building, distinguished mainly by that air of dignified antiquity which a western edifice knows how to assume before the men who built it are dead, should be able to turn out every 24 hours a full day's ration of flour for a state the size of Illinois.

Something of the mystery is explained to him when he enters the mill, for his first exclamation almost invariably is, "Where are the men?" Here and there he sees an oiler furtively dodging in and out among the close-packed masses of machinery; a sweeper or two can be discovered in odd corners; once in a while a white-coated miller appears at the end of a vista, opens something, looks in, closes it again, and passes on. Of

factory hands as most industries understand the term there seem to be none; no rows of operatives at benches or looms; no vast workrooms where the space has to be measured by the number of cubic feet of air required for each inmate. The mill seems to be running itself, and even the few men one does see appear to have only the vaguest connection with its operation.

This simple fact, so obvious to the miller and so mysterious to the outsider, explains the whole story. Most manufacturing plants have their size determined for them by the number of men and women they employ; the size of a flour mill is essentially regulated by the amount of machinery to be put in it. If human hands played much part in the manufacture of flour, a building thrice the size of the Pillsbury A would not suffice for the production of 14,000 bbls of it a day. As it is, every available cubic foot of the structure seems to be filled with machines. They rise from the floor; they hang like stupendous sloths from the ceilings; they reach out threatening arms at you from the walls. And, unless you know just what they are doing, they give you an extraordinary sense of loneliness. They are not interested in you, or in anything else but just performing their gigantic routine, hour after hour, day after day, week after week.

And yet, as the visitor progresses through the mill, and gets some faint notion of what is going on there, these dingy, impersonal machines take on individuality. He begins at the top floor, which is like the heights of Goethe's Brocken on the night of the witches' Sabbath. All around him dance huge, amorphous things, with multitudinous legs, breathing fine white dust. Some are round, some square, and they dance and dance and dance to the music of their own rattling, a portentous shimmy of giants. They dance till you expect them to leave their places and in pairs to clasp one another to their bosoms in a frenzied waltz; they shake their canvas legs, and the whole building seems to throb with their emotions. They do not stand in orderly, straight rows, nor are they all of a kind; each one, fat

grandmother, puffing uncle, squat baby, has sought out an available few feet of floor space on which to perform his solitary dance. You are told that their function is to sift, but you know perfectly well that this is a mere euphemism; their business is obviously to dance this devil's hornpipe, up there on the top floor all by themselves, with nobody watching them and no music that human ears can hear.

If the sifter floor is indecorous, the floors occupied by the purifiers are models of staid respectability. The purifiers sit like old ladies at a lecture, knitting; there are too many old ladies, and they squeeze each other uncomfortably, but they go on knitting, knitting, knitting. The lecturer has a droning voice, and nobody cares at all what he is saying, or expects him ever to stop; his tones are those of machinery which is in no hurry. A man has no place in this chaste conclave, anyhow; the mill operatives evidently feel this, for you do not often meet them there, and you yourself feel that it is just as well to hurry downward and escape from that interminable, drowsy knitting of the purifying old ladies.

The grinding floor, the largest grinding floor in the world, is another matter, convincingly masculine. Here you get the enormous, impersonal efficiency of machinery; a little of the feeling Meredith compressed into two lines when his Lucifer beheld the stars of night:

"Around the ancient track marched, rank on rank,
The army of unalterable law."

There they stand, rows on rows of machines, as uniform as soldiers on parade, doing their work without the appearance of motion. Here, on this floor, is the sum of human progress for uncounted centuries in the grinding of grain; all in the milling process that has gone before simply leads up to this stage, and all that comes after is but the conclusion of it. The grinding floor is discipline made tangible, and the closely packed machines (for the room does not seem large) stand for the

absolute maximum of accomplishment, with no thought for anything else.

But the real giant of the mill lives down below, down under the level of the river itself. You begin to feel his power as you pass from the grinding floor to where incalculable lengths of transmission rope carry the strength of his enormous arms up and in every direction; you feel it still more when you look at the huge incline of the main drive, its mile of two-inch cable passing up and down endlessly over the 34 grooves of the great sheaves. The giant himself is in a cave at the foot of interminable steps, a cave drilled out of the solid rock, where blasting even was impossible. He is really two giants, one part of him with the strength of 2,000 horses and the other that of 3,000. When you have just witnessed what he does, you are surprised that he is no larger; like the mill he operates, he represents close-packed power with no waste of space or size.

Such, in brief, is the largest flour mill in the world as the visitor sees it. When he goes away, he remembers the old gray stone building as the fitting home of incredible machines; that men work there he knows, for he saw them in the packing and shipping rooms; but the men were a mere incident, interlopers in a place belonging to beings more powerful by far than they. And when, thereafter, he sees factories devoted to other kinds of manufacture, sees the hundreds and thousands of operatives bending over their tasks, he remembers a building, seeming small by comparison, where every available foot of space was inhabited by a tireless force, working night and day to produce the food which has become the world's byword for the very means of life itself.

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